National Snow and Ice Data Center
Supporting Cryospheric Research Since 1976

Can we Produce Realistic Seasonal Forecasts in the New Arctic Paradigm?

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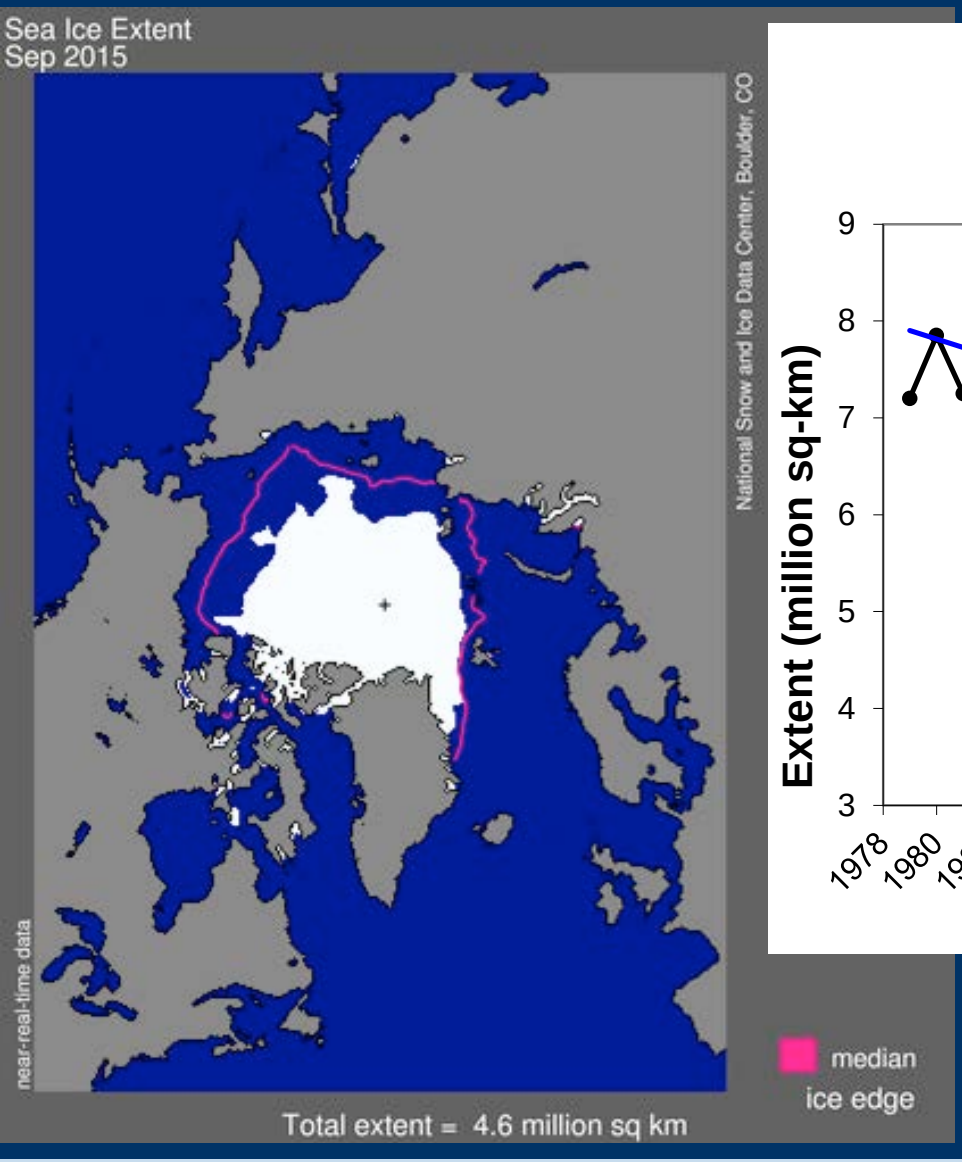
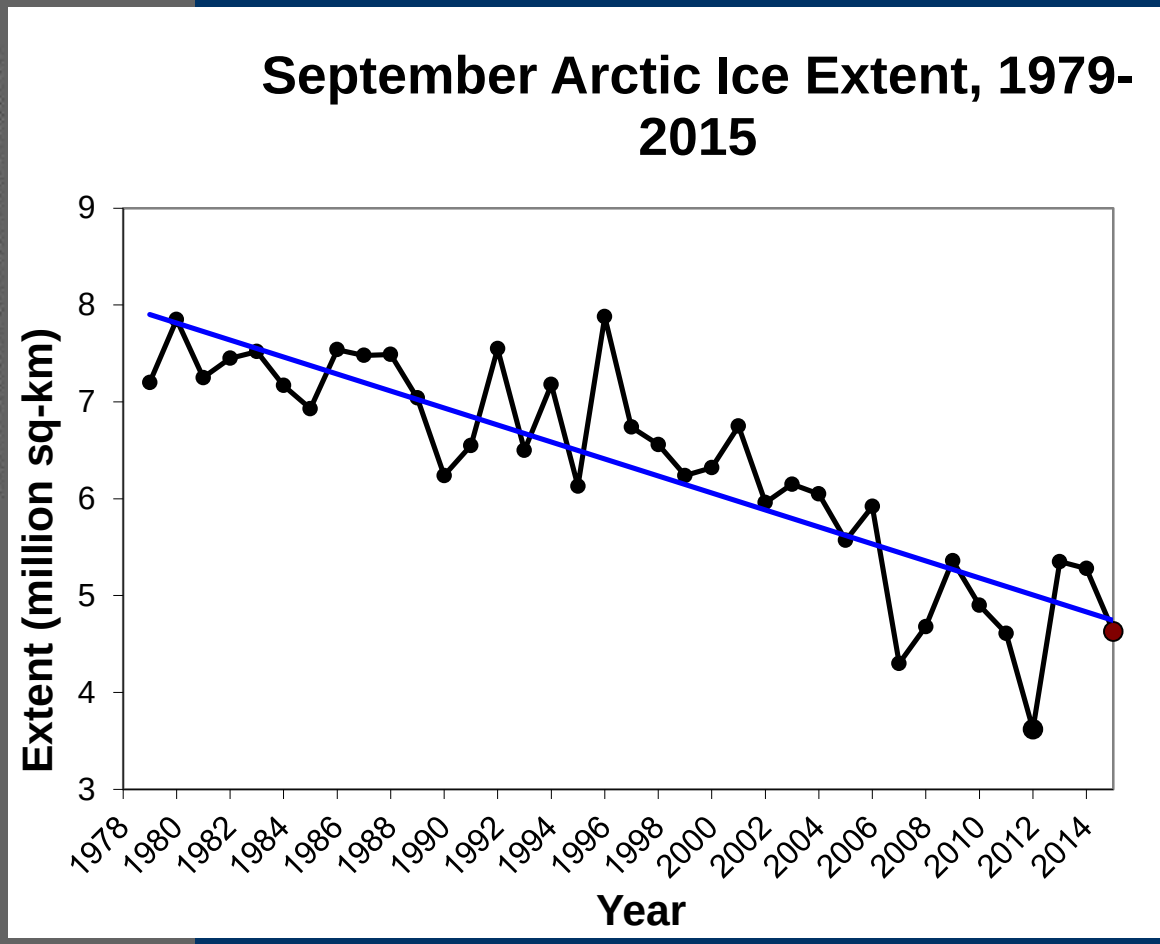
The shrinking summer ice cover



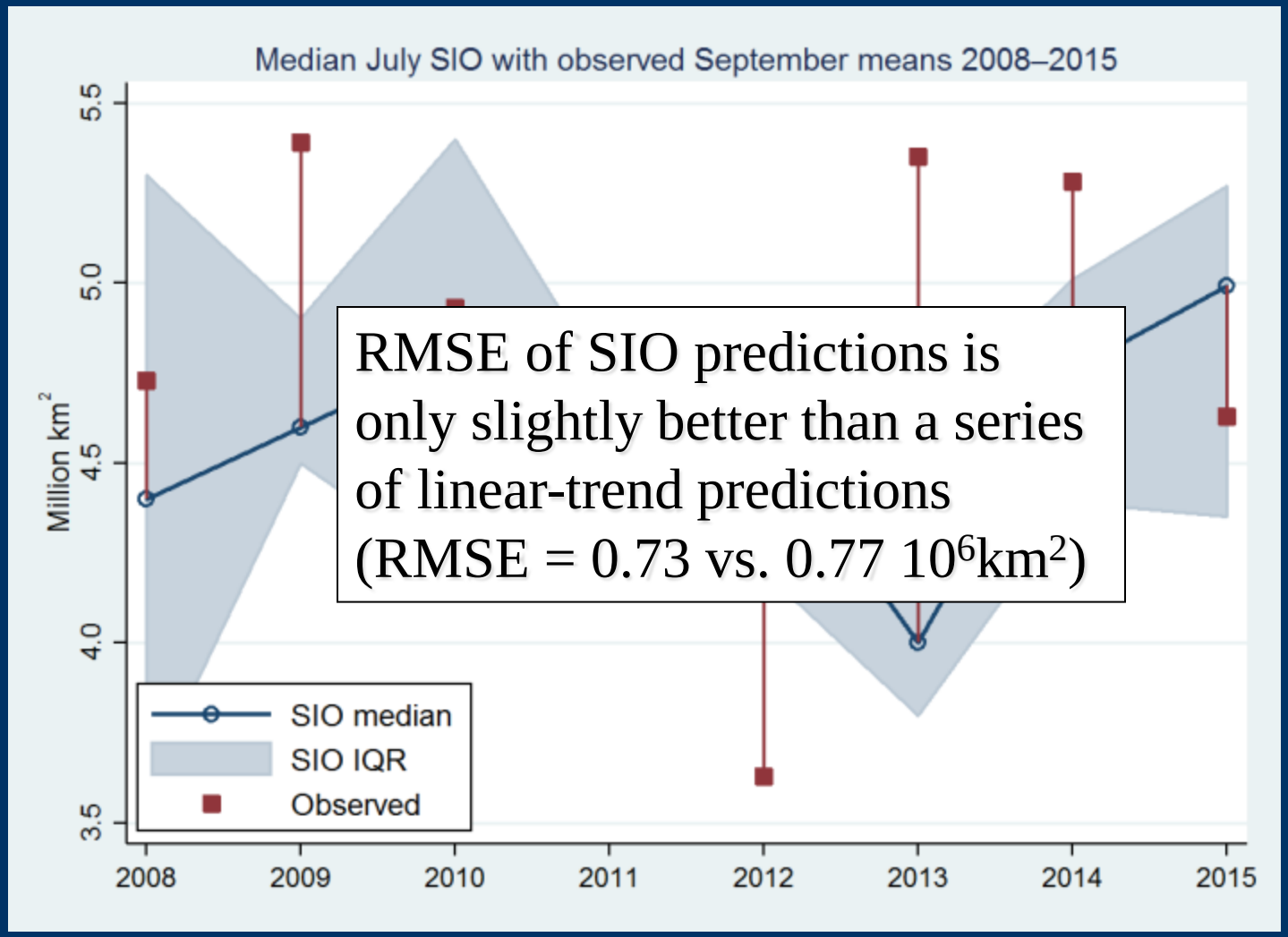


September 2015, 4th lowest on record

The Sea Ice Prediction Network (SIPN)

- Predicting Arctic sea ice a few months in advance has become a challenging priority.
- Since 2008 SEARCH has solicited community predictions of the September minimum sea ice extent.
- Individuals and teams employ a wide variety of modeling, statistical and heuristic approaches to make these predictions
- SIPN now manages the SIO and disseminates results through the SEARCH Sea Ice Outlook (arcus.org/sipn/sea-ice-outlook
- Since 2008, there have been 953 contributions.

A look back: SIO Predictions 2008-2015

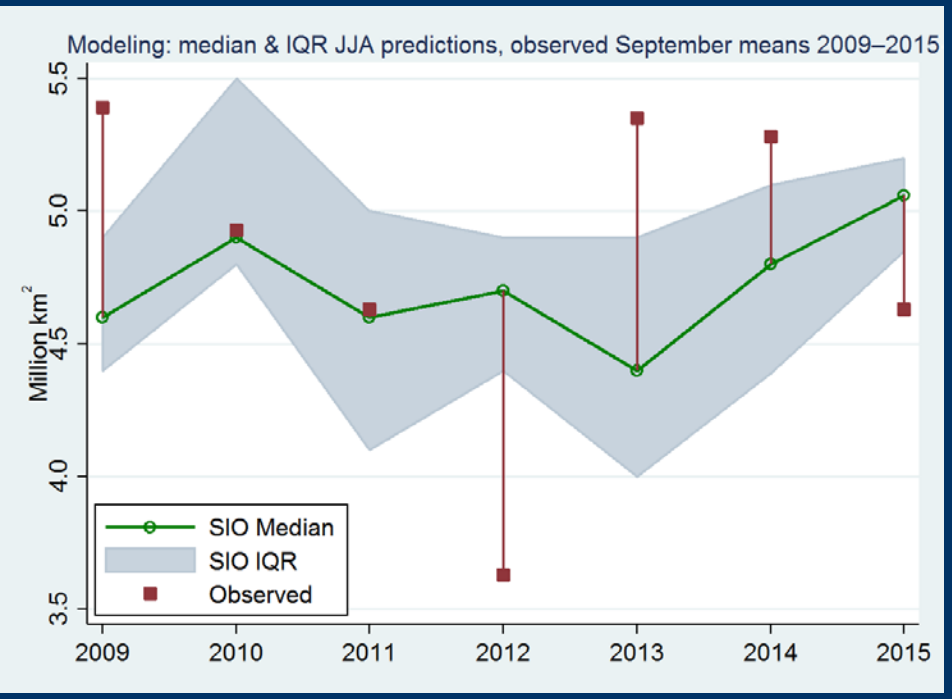


RMSE of SIO predictions is only slightly better than a series of linear-trend predictions (RMSE = 0.73 vs. 0.77 $10^6 km^2$)

In difficult years, observed September sea ice fell well beyond interquartile range (IQR) of SIO, and outside most individual confidence intervals

Figure from L. Hamilton

Forecasts: Statistical vs. Dynamical Models



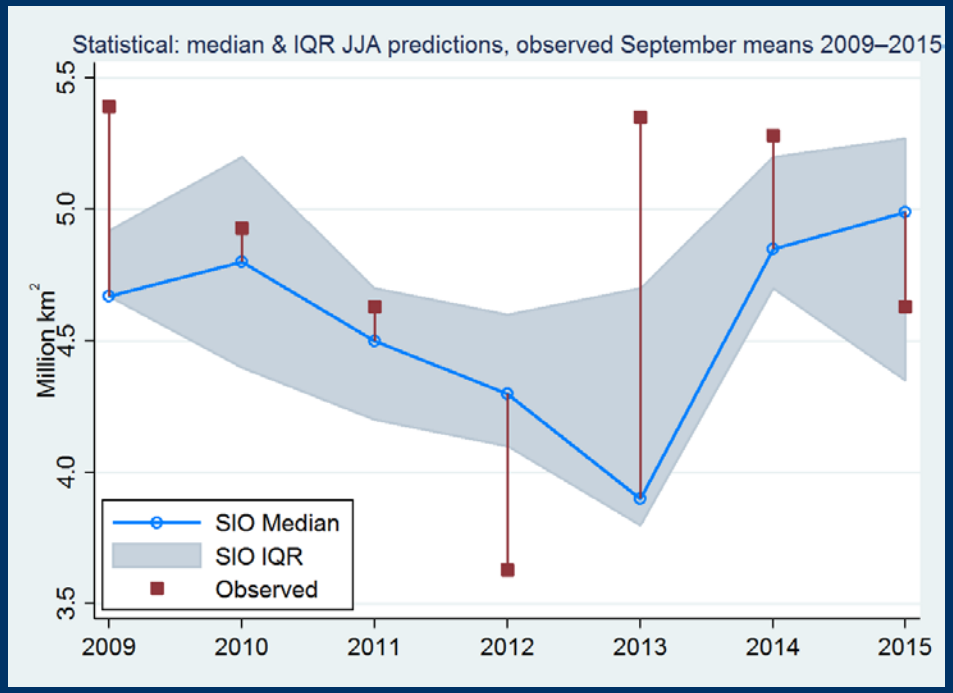


Figure from L. Hamilton

- SIO statistical forecasts (right) and dynamical models (left) show the same years difficult to predict.

Comparison by method: 2013-2015

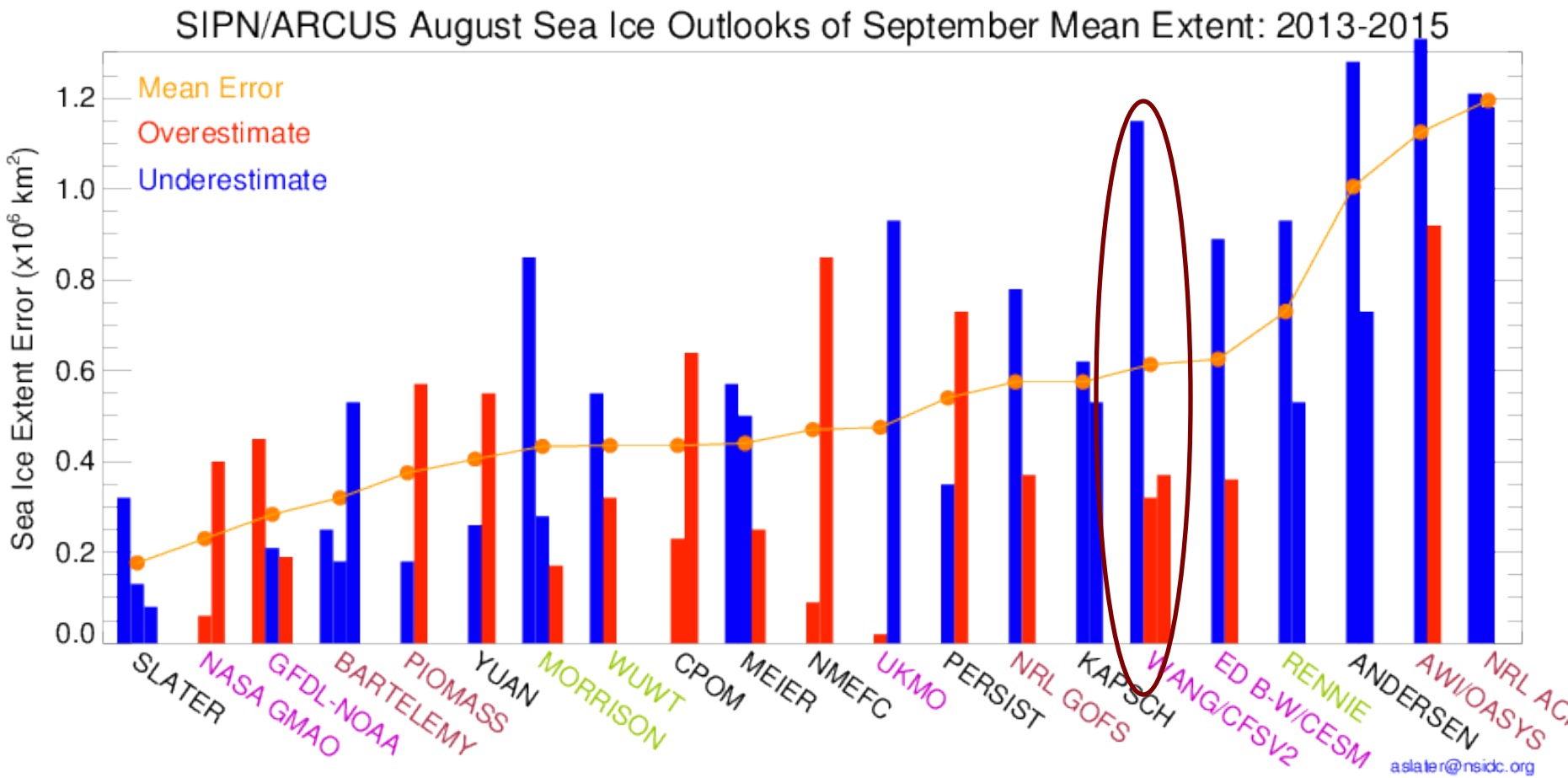


Figure from D. Slater

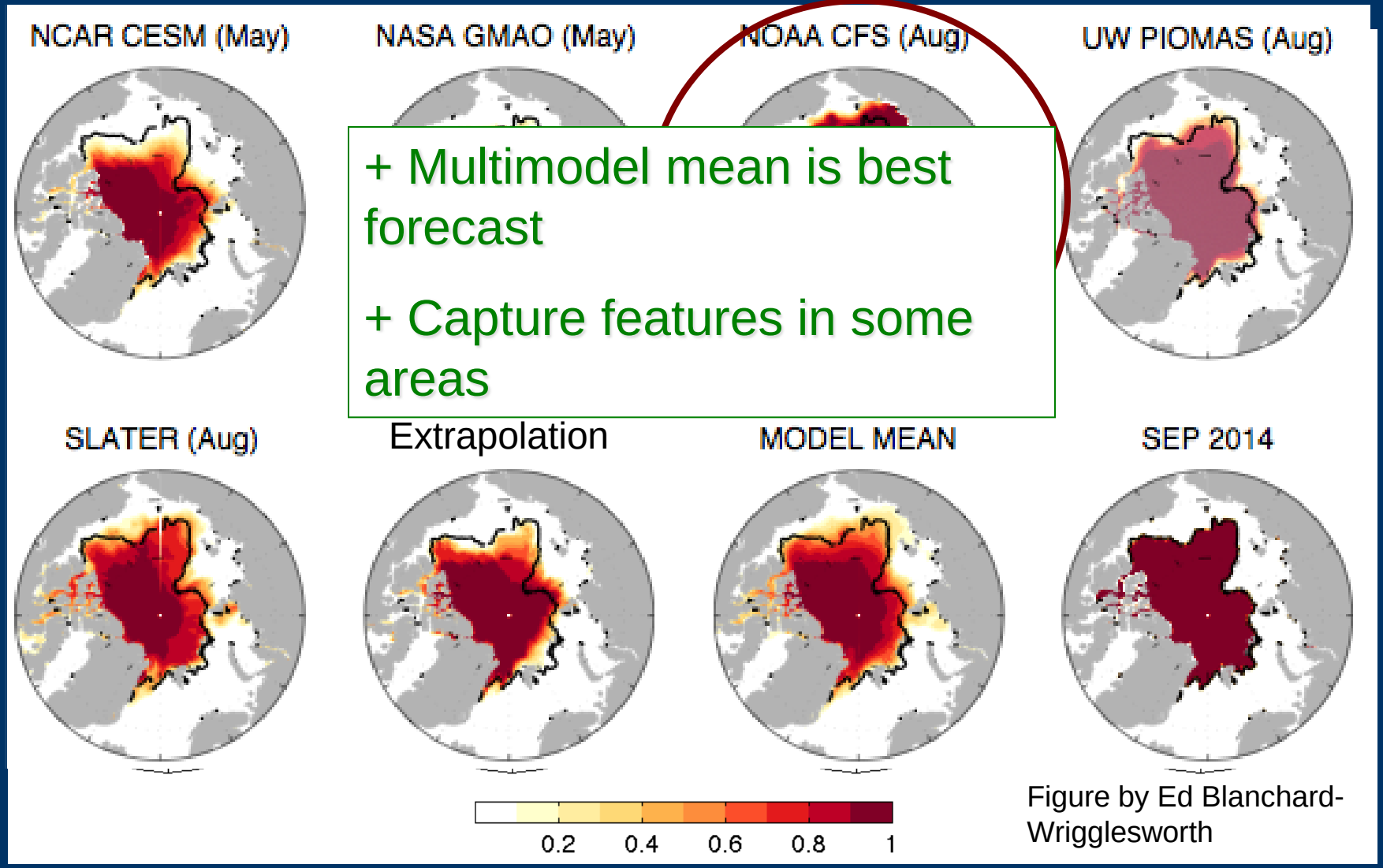
Black = Statistical

Red = Ice-Ocean

Pink = Coupled Atmos-Ice-Ocean

Green = "Other" i.e. a guess

SIO spatial distributions: Probability of Ice (2014)



+ Multimodel mean is best forecast

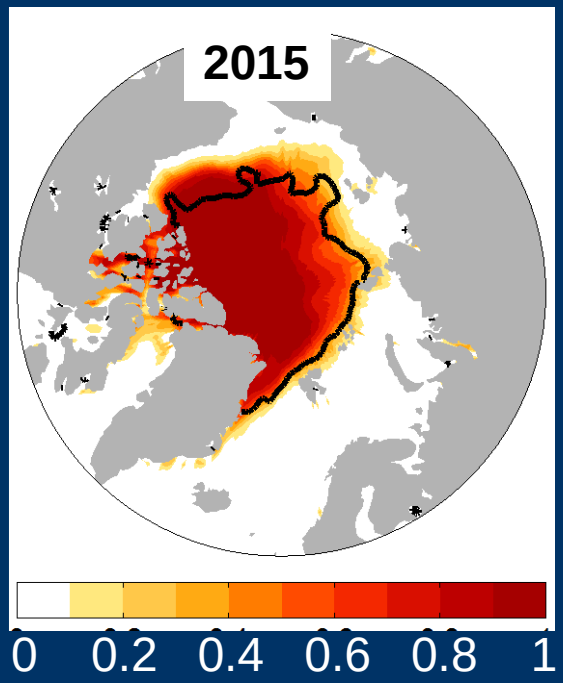
+ Capture features in some areas

Figure by Ed Blanchard-Wrigglesworth

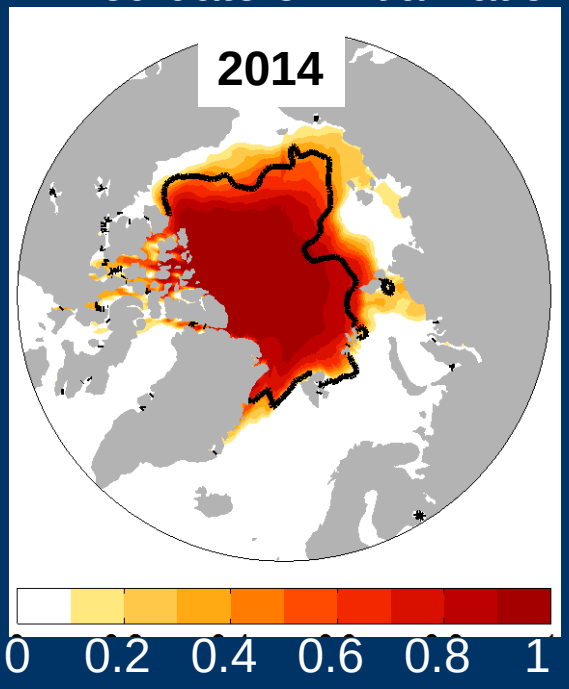
Probability of ice (2015 vs. 2014)

Multi-model mean forecast (colors)
with observed extent (black line)

May/June initialization



Mixed date of initialization



Forecast Difference

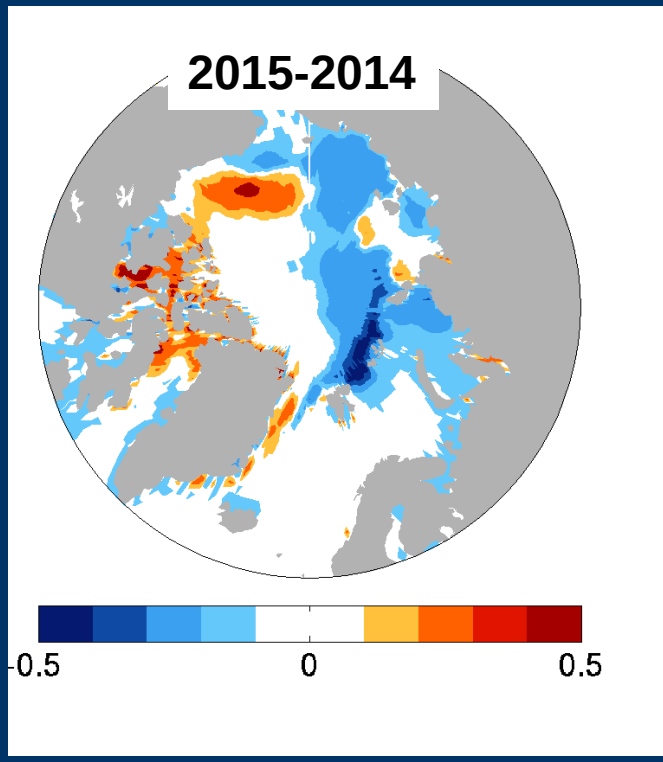


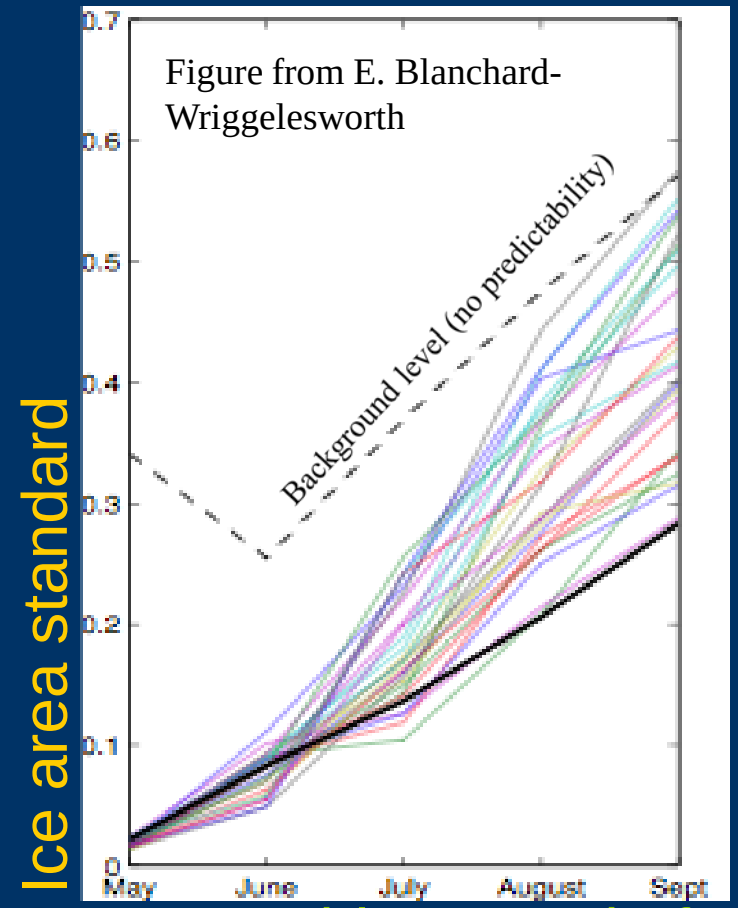
Figure by Ed Blanchard-Wrigglesworth & C. Bitz

2014 Forecasts: Slater, CFSv2, GMAO, PIOMAS, CESM
2015 Forecasts: GMAO, NRL, UCL-Belgium, MetOffice

Limits on predictability

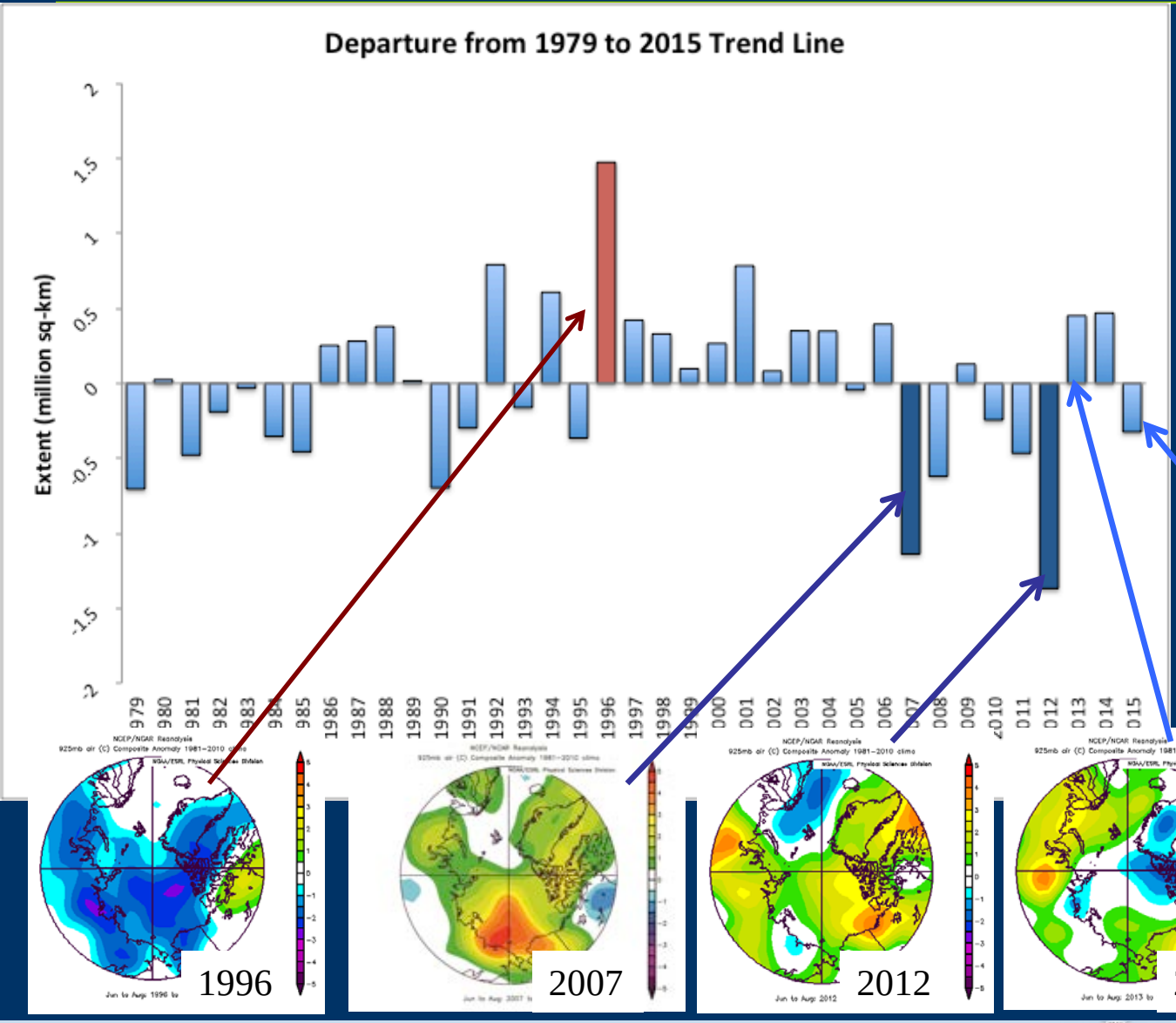
- GCM simulations show that different years can show very different predictability skill with the same initial conditions.

- This points to the influence of the chaotic (unpredictable) nature of summer weather.



Each colored line represents growth in GCM ensemble spread of forecasts for a particular year initialized in May.

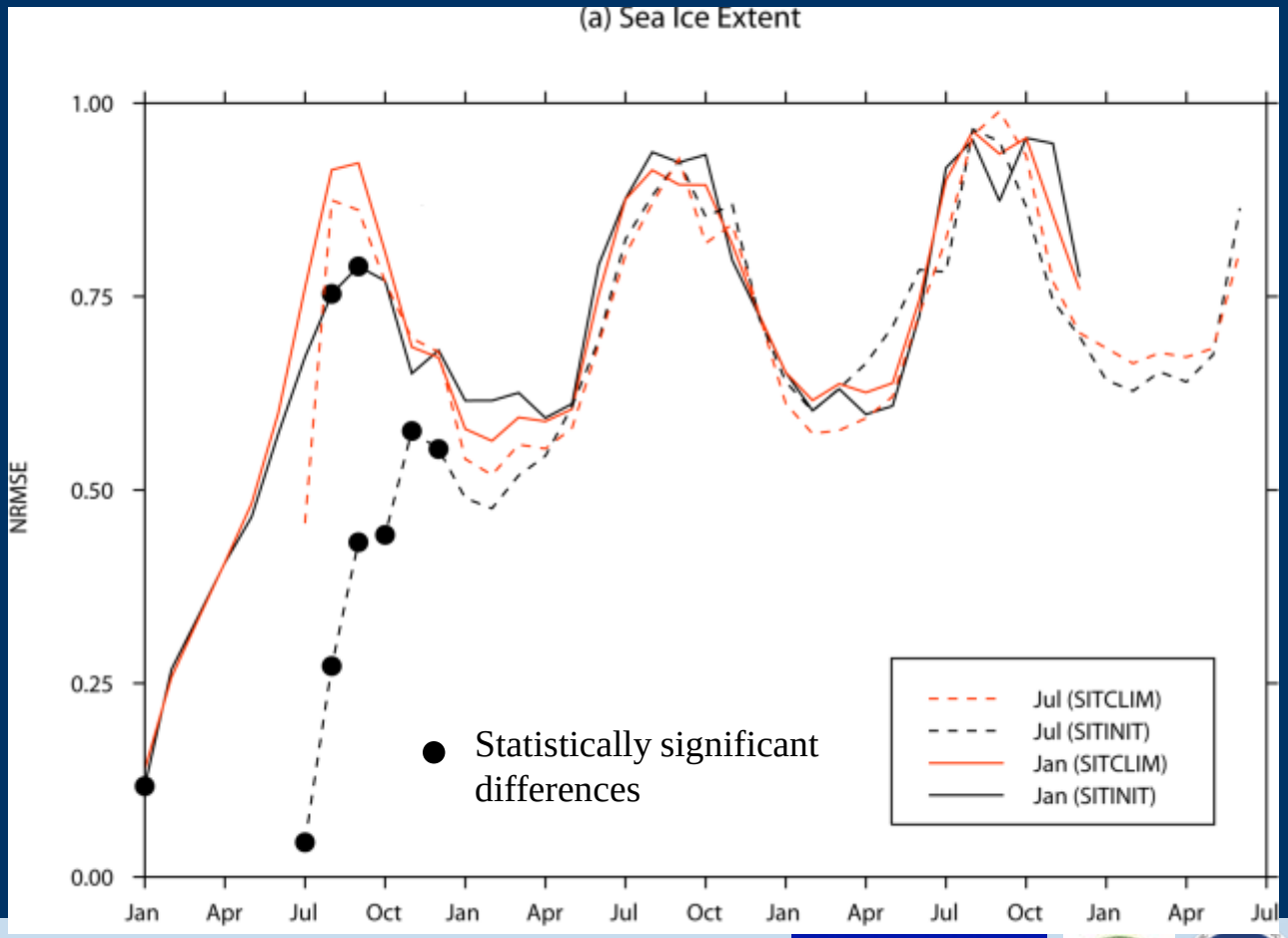
Importance of summer weather



- In the absence of strong anomalously summer weather, the extent will tend to return to the long-term trend line.

How to improve predictability? Initial conditions!

- Studies have suggested ice thickness could improve seasonal ice forecasts (e.g. Day et al., 2014).



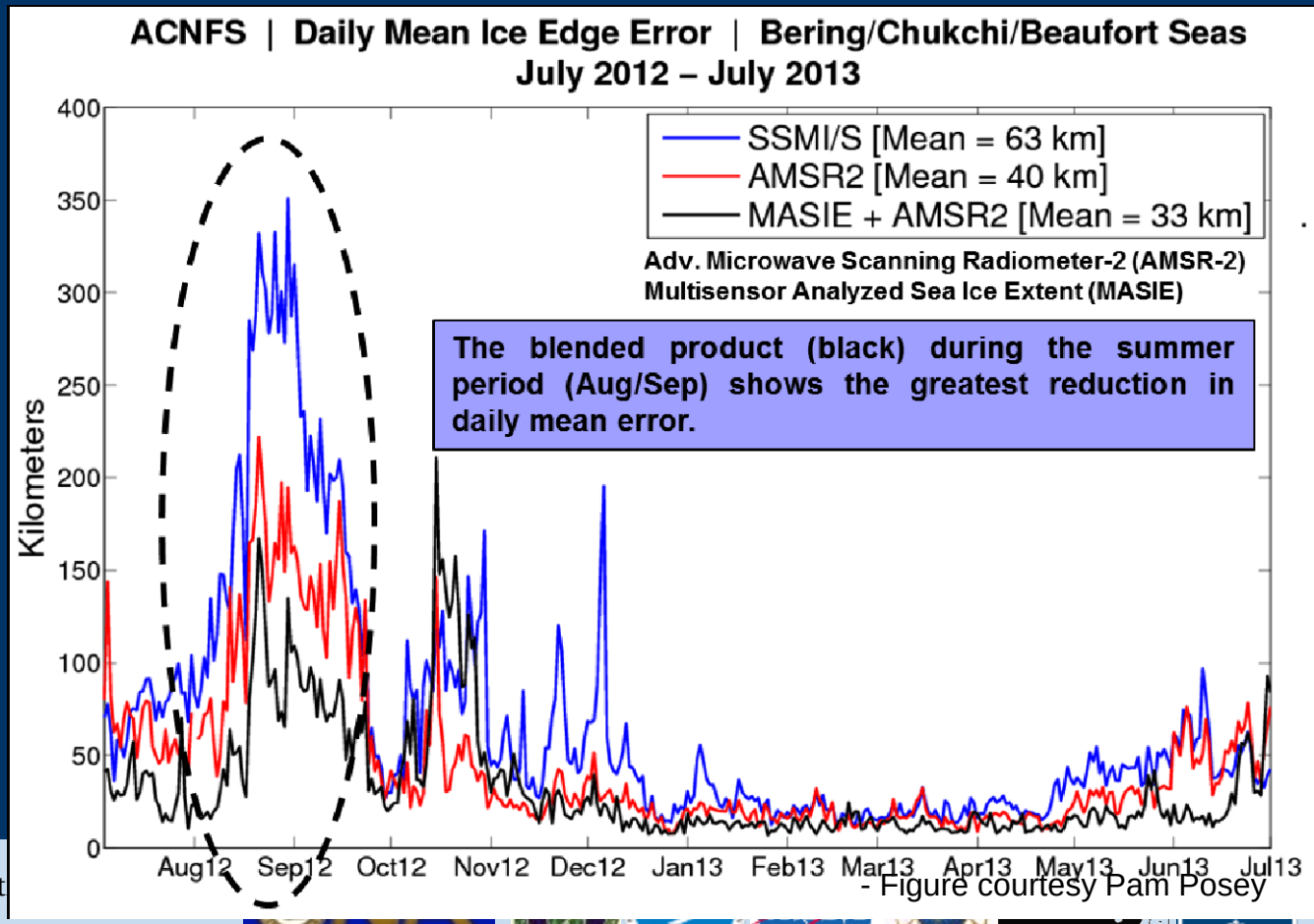
Accurate knowledge of thickness field reduces RMSE up to 8 months in advance.

Day et al., 2014

How to improve predictability? Initial conditions!

- Initializing with better ice concentration may improve forecasts.
- A blend of 4-km NIC ice extent (MASIE) with 10-km AMSR2 sea ice concentrations makes a daily ice product (MASAM2) that is more accurate for data assimilation.

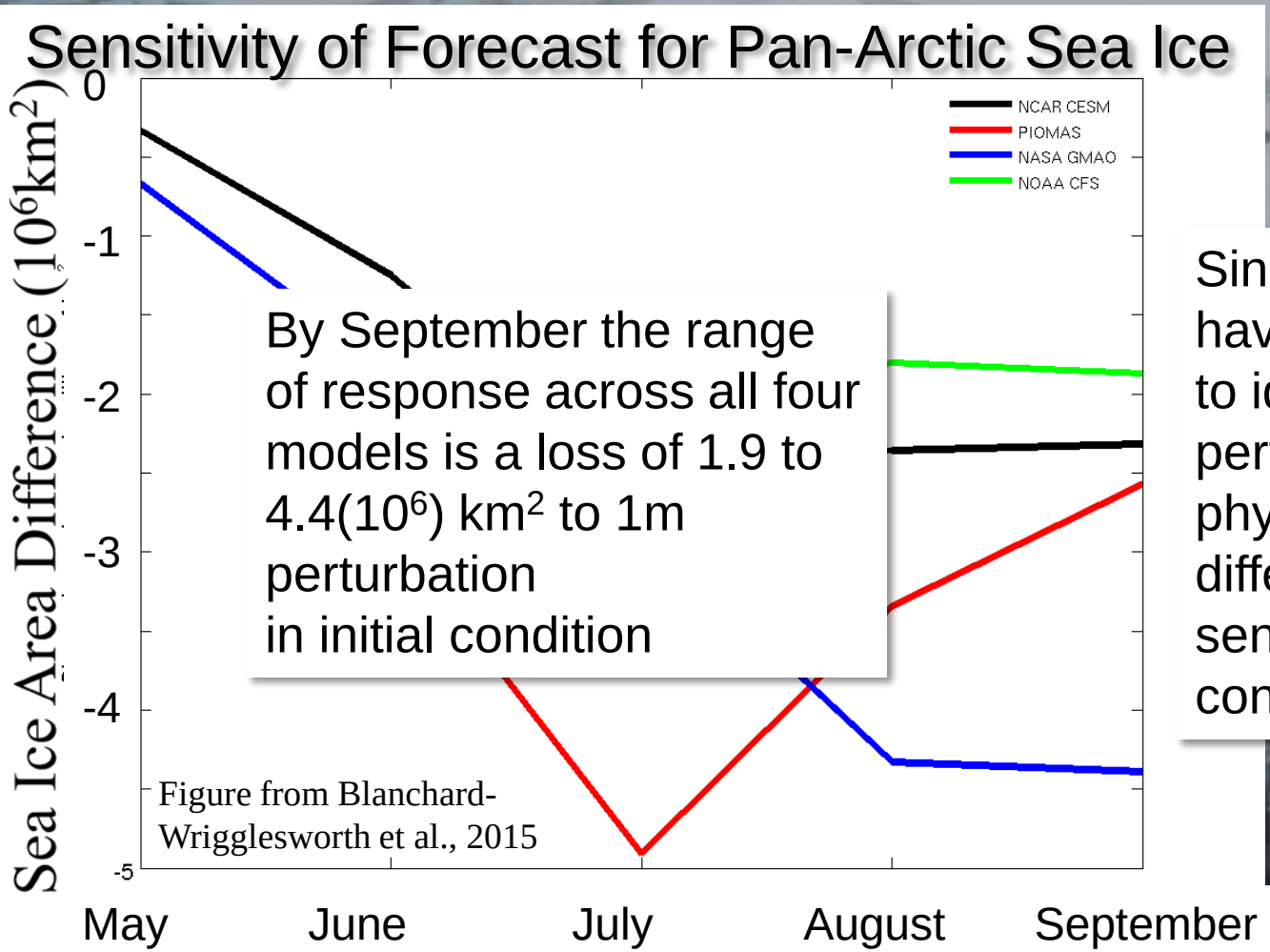
- NRL tested MASAM2 for short term hours to days forecasting.
- During summer months, ice edge location prediction improved by 60%.



- Figure courtesy Pam Posey

Sensitivity of SIO forecasts to initial conditions

In April 2014 we asked all SIO model contributors to reproduce their 2013 Forecast with a 1m perturbation to the initial thickness.



By September the range of response across all four models is a loss of 1.9 to 4.4(10^6) km^2 to 1m perturbation in initial condition

Figure from Blanchard-Wrigglesworth et al., 2015

Since the four models have different responses to identical initial condition perturbations, model physics likely result in different forecast sensitivity to initial conditions.

Recommendations for Forecasting Community

- There is a strong need for modeling groups to employ a common protocol so that it will be possible to:
  - Quantify the relative contributions from imperfect knowledge of initial conditions, chaotic atmospheric forcing and imperfect model physics from prediction in a realistic framework.
  - Incorporate an increasing number of sea ice observations in model initialization
    - e.g. sea ice concentration, thickness, snow depth, melt pond fraction, ice drift

Concluding Statements

- Analysis of nearly 1000 individual predictions submitted to SIO from 2008 to 2015 show a bimodal pattern of success.
- During years when the sea ice extent departs from the accelerating trend, predictions fail despite preconditioning.
- The pattern appears unrelated to the general type of method used, rather year-to-year variability dominates success.
- RMSE of predictions is slightly smaller (0.73 (10^6) km^2) than using linear trend for predictions (0.77 (10^6) km^2).
- There remains an inherent limit to predictability due to chaotic atmospheric variability.

- It is possible that summer ice extent has been less predictable in recent years compared to previous decades.

Thank You